# FABRIC FILTERS: AN EFFECTIVE MEANS OF AIR POLLUTION CONTROL IN THE FERRO-ALLOY BUSINESS

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## SYNOPSIS

This paper explains what pollution is produced in the ferro-alloy furnaces. It discusses the experience in collecting this fume in the U.S.A., the type of collectors, and consideration in selecting a fabric filter. It indicates some of the future problems to be solved.


Today's start-of-the-art with regard to ferro-alloy furnace fume control utilizing fabric filters covers some 25 years of effective air pollution control experience. In the United States alone, over eighty submerged arc ferro-alloy furnaces have been equipped with fabric filters for effective fume control. We have 70 worldwide installations ventilating 20 million cu.m./hr. The results are well documented and this paper will briefly review the state-of-the-art and identify new trends.

## FERRO-ALLOY EMISSIONS

What are we attempting to control? We use the term ferro-alloy fume, but what is it? How is it generated? And what is its nature? Through sampling and analysis, we find that it consists of finely-divided, solid-particulate matter with high electrical resistivity. We know that it is formed at extremely high temperatures within the furnace. From our study of metallurgy, we know that at these extremely high temperatures, base metal elements will vaporize, and as the vapor rises from the molten metal, it oxidizes, cools, and then solidifies into minute submicron particles, which we define as fume. In addition to fume-size particles, much larger particles of dirt, dust, rust, and incompletely combusted wood and/or coal and coke are carried out of the furnace into the atmosphere by the off-gases generated within the furnace.

## CHEMISTRY

The chemistry of ferro-alloy furnace fume is predominantly silicon dioxide but varies depending upon the metal being produced. During reduction, a white to a grayish-white silica fume is generated. A silicon monoxide is more volatile than either silicon or silicon dioxide, it has been postulated that silicon monoxide evolves as a gas, and, after striking the air, it immediately oxidizes, cools, and condenses into spherical submicron particles of silica fume.

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## PARTICLE SIZE

Let us look at a ferro-silicon fume sample collected with a thermal precipitator. In the sample, the largest particle is approximately 0.3 microns and it is relatively easy to optically determine that particles exist as small as 0.01 microns. Gas-borne solids smaller than 0.01 microns are difficult to find individually in any great quantity. Groupings of 0.01 micron particles exist, demonstrating the tendency for these extremely fine particles to agglomerate.

Silverman and Davidson report that the particle size of ferro-silicon fume is between 0.01 and 4 microns with a geometric mean dimension of 0.3 to 0.4 microns based on a number of samples, which were analyzed for size and composition. The furnace tested was equipped with a semi-enclosed hood and was producing 50% ferro-silicon metal and sampling was conducted in the stack directly above the hood. During blows, particles as large as 40 microns were obtained and identified.

Union Carbide Corporation has reported particle size from ferro-silicon operations in the range of 0.02 to 0.25 with an average size of 0.12 microns.

Ferro-manganese fume is much larger in particle size than ferro-silicon fume and silicon metal fume. Rudolph, Harris, Gresser and Levins have reported, based on field measurements of the effluent from a closed ferro-manganese and silico-manganese furnace, that 88% of the particulate matter is in the 3 - 10 micron size range. Earlier reports indicate that the particulate emissions from a ferro-manganese operation averaged eight microns with 14% over 250 microns. It is reasonable to expect that the particle size from ferro-chrome operations would be in the same size range as ferro-manganese and silico-manganese.

All of this submicron material must be separated from the furnace off-gas in order to obtain effective fume control. But, moreover, the control equipment engineer must have an accurate insight into the particle size distribution curve if he is to accurately predict (a) the pressure drop of a fabric filter for a given application or (b) the energy requirements of a high-energy scrubber necessary to meet a given outlet condition.

## QUANTITY

The quantity of particulate matter has been checked from numerous control systems, and the amount varies greatly, depending upon conditions of the charge material, the frequency of blows, the furnace design, and operation practice. In a covered furnace the concentrations range from 10 to 70 grams/cubic meter. In an open furnace the concentration would be 1/2 to 5 grams per cubic meter. The difference is primarily due to the much lower volume from a covered furnace.

The make-up of the off-gas consists of combustible gases generated through (1) electrode consumption, (2) vaporization and dissociation of oil and water in the charge, and (3) chemical reduction plus infiltrated air. At high temperatures, up to 2 000°C, a chemical reduction reaction occurs between the metal oxides and the reducing agent. The products of the reaction are molten alloy and carbon monoxide. Surprisingly, carbon monoxide is the major by-product of ferro-alloy production. The weight of CO emitted from the melt can exceed the weight of the alloy being produced. In a 45% ferro-silicon furnace, the amount of carbon monoxide emitted was 2 tons for every two tons of ferro-alloy produced.

The amount of infiltrated air in the off-gas will vary widely depending upon the method of fume and off-gas capture. The more open and higher the hood, the greater the amount of total off-gas requiring treatment.

## GAS CLEANING EQUIPMENT

To date, the tools of particulate air pollution control for submerged arc electric furnaces producing ferro-alloy have been the wet scrubber, the electrostatic precipitator and the fabric filter. Let us review each one separately.

## WET SCRUBBERS

Considerable experience has been acquired throughout industry in the application of many designs of wet dust collectors to collect many different kinds of dust from a variety of sources. From time to time, these have been applied to submerged arc electric furnace fume with limited success.

In the United States ferro-alloy industry approximately twenty furnaces have been equipped with high-energy orifice or venturi-type scrubbers. They have been used on closed furnaces due to their ability to handle explosive mixtures and temperature overruns.

Recognized disadvantages are: (1) higher operating energy costs in the range of 300% over the fabric filter, (2) potential water pollution problems, and (3) potential corrosion problems.

The lower operating temperature of the high-energy scrubber reduces the volume of the gas to be cleaned, reducing the size of the ductwork and scrubber. This reduction is offset by increased cost of the high-pressure fan, larger motor and starter, and water-handling equipment. The best comparison indicates that the high-energy scrubber, including the sludge-handling equipment, is approximately 15% more expensive than a fabric filter. Without the sludge disposal system, the price of the venturi scrubber is approximately 5% less. On smaller furnaces, the high-energy scrubber appears to be appreciably more costly than the fabric filter.

## ELECTROSTATIC PRECIPITATORS

In view of the wide acceptance of the electrostatic precipitator as a means of effective gas cleaning throughout industry, it is surprising to find so few in use as pollution prevention devices in ferro-alloy plants today.

Because of the high resistivity of the ferro-alloy fume and its fine particle size, the gas cleaning industry generally does not regard the application of electric precipitators for cleaning submerged arc furnace gases as ideal.

FABRIC FILTERS

Product recovery from stack gases by the use of filter fabrics has resulted in the development of an effective means of gas cleaning often referred to as a best means of obtaining the highest consistent recovery of gas-borne particulate matter. Production requirements have demanded reliability and durability of design, which have been achieved.

Surprisingly enough, a bag house, or a fabric collector if you prefer, represents a rather versatile device for the abatement of particulate air pollution. It has a uniform, high-collection efficiency regardless of varying temperature, varying moisture, varying dust load, and varying volume. Field efficiency tests handling submicron electric furnace fume in the range of 2 grams/cubic meter fume load have consistently resulted in efficiencies in excess of 99% by weight and an effluent free of visible solids.

In North America, the first furnaces controlled were of the open type handled with low temperature fabrics in a shaker type collector. As the ferro-alloy industry developed closer more restrictive furnace openings and higher temperatures of the off-gases the use of glass fabrics were required. In the early 60's the collectors installed had glass bags which were either cleaned by reverse air or by a combination of shaking and reverse air. These collectors had a limitation of 2 to 1 air to cloth ratios and about 2 yrs. baglife.

The next development occurred in the early 70's when nomex was used to replace the glass in existing shake and reverse cleaning collectors with higher true put. The air to cloth ratios improved to around 3 to 1 and baglife increased to some 3 yrs. where good maintenance practices prevail. At this time these collectors featured isolatable maintenance compartments although most were opened pressure designs which allowed inspection, during operation of any compartment.

The next step forward in the use of fabric filters occurred in the middle 70's after some earlier comprehensive pilot testing in Norway. This design featured the outside bag collector or pulse-jet type of filter. With the development of new fabrics for use with this type of filter operation, higher air to cloth ratios are possible. This type of collector has the ability to handle high grain loadings which made it a natural choice for use in the ferro-alloy industry. It could be effectively combined with a heat recovery system which decreased the air volume and increased the dust load to the filter.

Since reverse air, shaker, and pulse type of collectors all offer efficient and cost effective fume control you have a number of factors to consider in selecting the proper fabric filter. The most critical is the sizing of the selected unit which will directly influence the capital cost, the erection cost, the pressure drop across the filter, and will also effect the cloth and cage life. Since the selected filter size varies from application to application and with the type of filter, the design criteria should be accurately determined from field experience. You will also wish to get accurate estimates of the baglife, the cage life, compressed air requirements, and operating pressure drop.

Two designs may vary widely in first costs. The design having the lowest first cost will oftentimes have the highest operating costs. Therefore, the accuracy of determining the operating costs of a specific design is essential in order to make the optimum selection.

## U.S. POLLUTION CONTROL TRENDS

The trend in pollution abatement programs is the ever increasing stringency of air pollution control regulations. And now recently, in addition to particulate emissions, the United States Environmental Protection Agency has taken an interest in the effluents of hydrocarbons and trace metals, including mercury and arsenic, from ferro-alloy plants. The EPA has reported preliminary data from a plant in Norway which show that a closed furnace system efficiently lowered the quantities of particulate emissions but that these emissions contained a high percentage of hydrocarbons. The major sources of organic material in the ferro-alloy process effluent are the self-baking carbon electrodes and coal and coke added to the feed. Accordingly, the EPA funded field test work to sample the emissions from the Union Carbide ferro-alloy plant at Beauharnois, Quebec, Canada.

Emission tests at Beauharnois were conducted both during silico-manganese and ferro-manganese production runs. The control system consisted of a closed furnace incorporating a high-energy venturi scrubber. The test work indicated that while the trace metals effluent was low, generally less than 1 $mg/m^3$, the estimated arsenic level was 250 $\mu g/m^3$. Comparisons of this estimated value with the minimum acute toxicity effluent criterion of 2 $\mu g/m^3$ for arsenic and its compound indicate that more extensive analysis of arsenic in ferro-alloy plant emissions may be warranted.

The question of polycyclic organic material (POM) control also requires additional field testing. From experience and work on other metallurgical applications, it would appear that secondary combustion within an open hood would greatly reduce POM emissions from the furnace before entering the control device. The Beauharnois field work indicates that the scrubber at Beauharnois appears to be effective for the control of POM on the Beauharnois furnace.

## DISPOSAL

A problem that requires additional attention is fume disposal. As more and more shops install effective means of gas cleaning, a substantial increase in the amount of material to be disposed of will warrant research and development in order to provide a better answer than what is available today.

## CONCLUSION

Ferro-alloy furnace fume control is neither simple nor insurmountable, but it is a highly technical problem requiring engineered answers. The fundamental development work of the 1950's, 60's and 70's is being displayed with justifiable pride. However, recognizing the ever increasing stringencies of governmental regulations, much remains to be done in the evaluation and development of optimizing the most effective solutions for the most economical control system.

## DISCUSSION

Mr. M. Sciarone*

Mr. Goss makes his comparison between the cost of a fabric filter and of venture scrubber. Does he compare cubic meter by cubic meter or cubic meter from a closed furnace and from an open furnace after dilution of a hundred times to a fabric filter?

Mr. W. Goss:

Those cost comparisons for which I accept no responsibility, myself, came out of a study for two furnaces which we were looking at, both closed furnaces, looking at both methods of control and those were actually cost generated for the furnace, for the required flows, not for the cubic meter to cubic meter comparison.

Mr. M. Sciarone

It seems in our experience that there is a considerable difference in the cost of an open furnace with a fabric filter which is at least 4 - 5 times of a closed furnace, I can assure you of that. But, besides that, the other question is about the potential corrosion problem. We have a wet scrubber at a plant, but also a fabric filter. The wet scrubber we have so far is maybe a potential but not a real corrosion problem, but on the bag filter, a lot of acid too goes through it and there is also some moisture and at cold spots we get serious corrosion problems. So I would like to mention that the fabric filter is not without a corrosion problem. This may occur there as well. Is it your experience as well?

Mr. W. Goss:

Yes, we have seen some corrosion on the fabric filters and I would suggest that corrosion is a consideration on the fabric filters that you have to face also. I do agree with you.

Mr. M. Sciarone

And then on the wet scrubber we have a problem with the water pollution that's quite true. On the bag filter, we have a problem with the dry materials as you mentioned later and you must really think on it. It is really difficult to find a good solution to it.

Mr. W. Goss:

Yes.

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